CPDS Instruments Aboard the ISS

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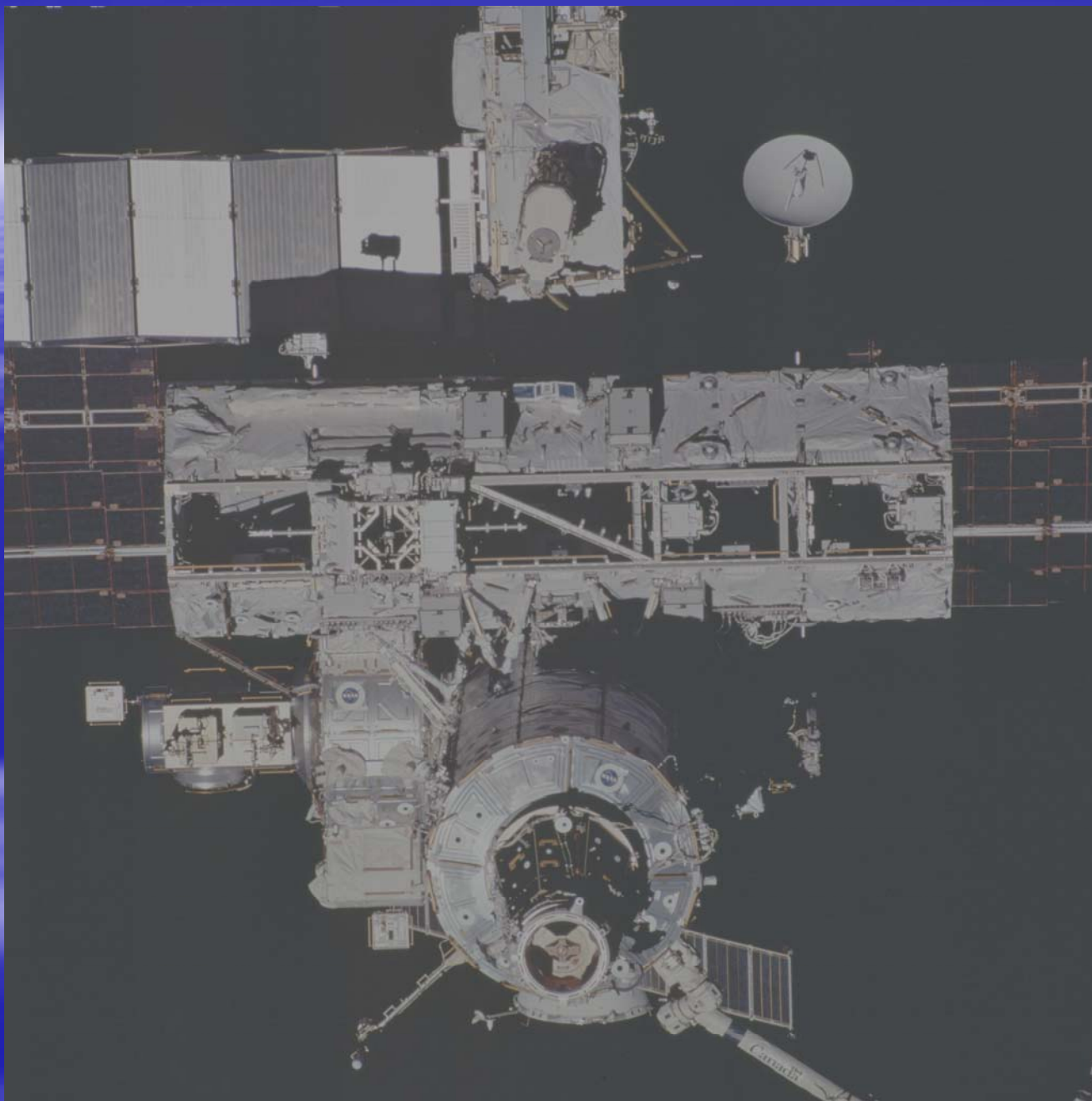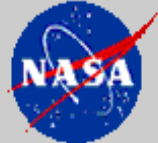(1) University of Houston, 4800 Calhoun Rd., Houston, TX 77204
(2) Lockheed Martin Space Operations, 1300 Hercules Suite 100, Houston, TX 77058
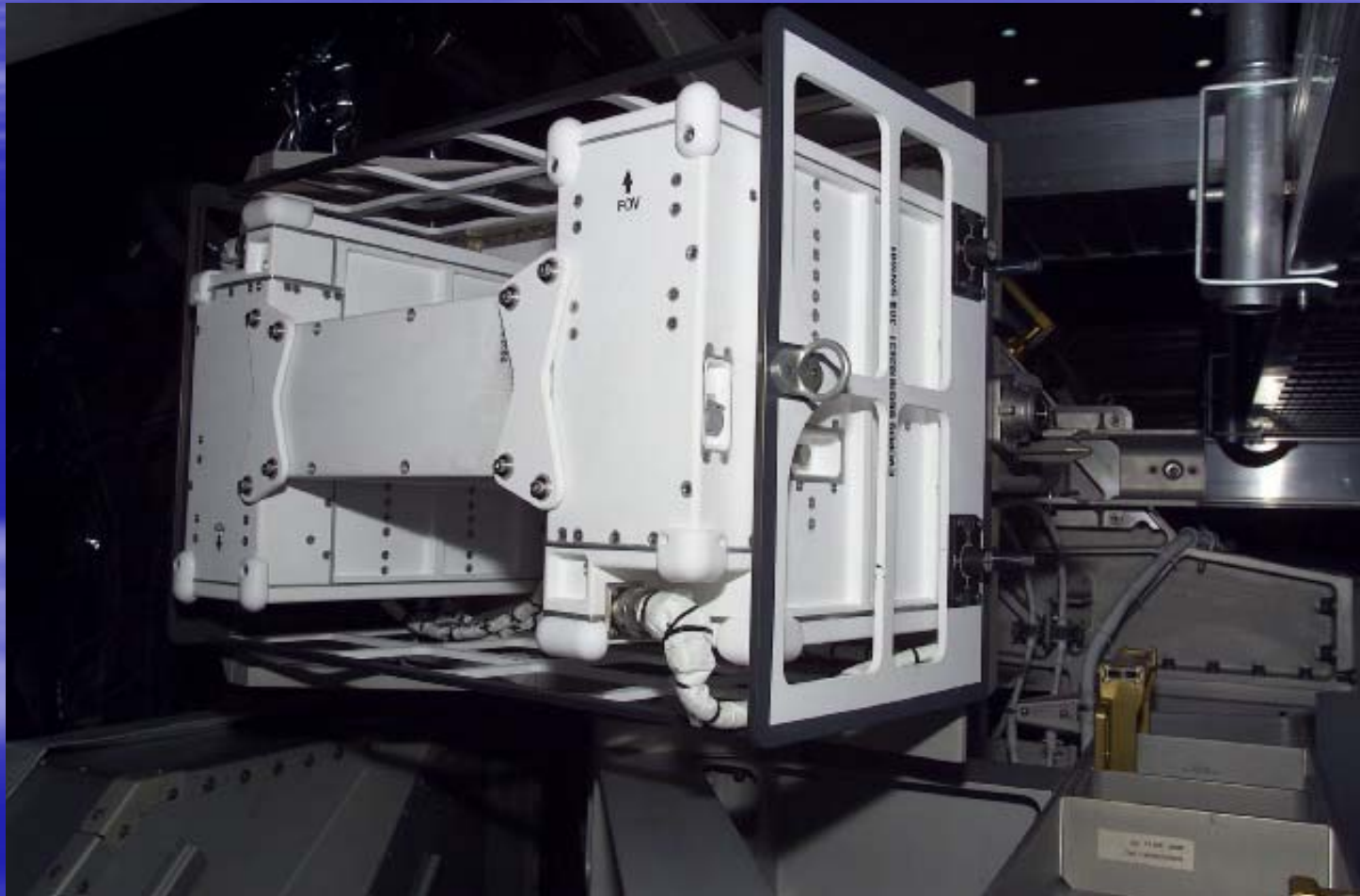(3) Jacobs Sverdrup, 2224 Bay Area Blvd., Houston, TX 77058

Introduction

- CPDS – Charged Particle Directional Spectrometer
- IV instrument is placed inside the USA Laboratory module of the ISS and it was activated on April 21, 2001
- EV instrument is mounted on the S0 truss of the ISS, and was activated in late April 2002
- Instruments are presently taking data which is used for operational radiation dose level indicators
- Instruments are also capable of particle and energy identification
- These data can provide information about the composition of the lower radiation belts, shielding provided by Earth's magnetosphere, and differences in the radiation environments inside and outside the ISS
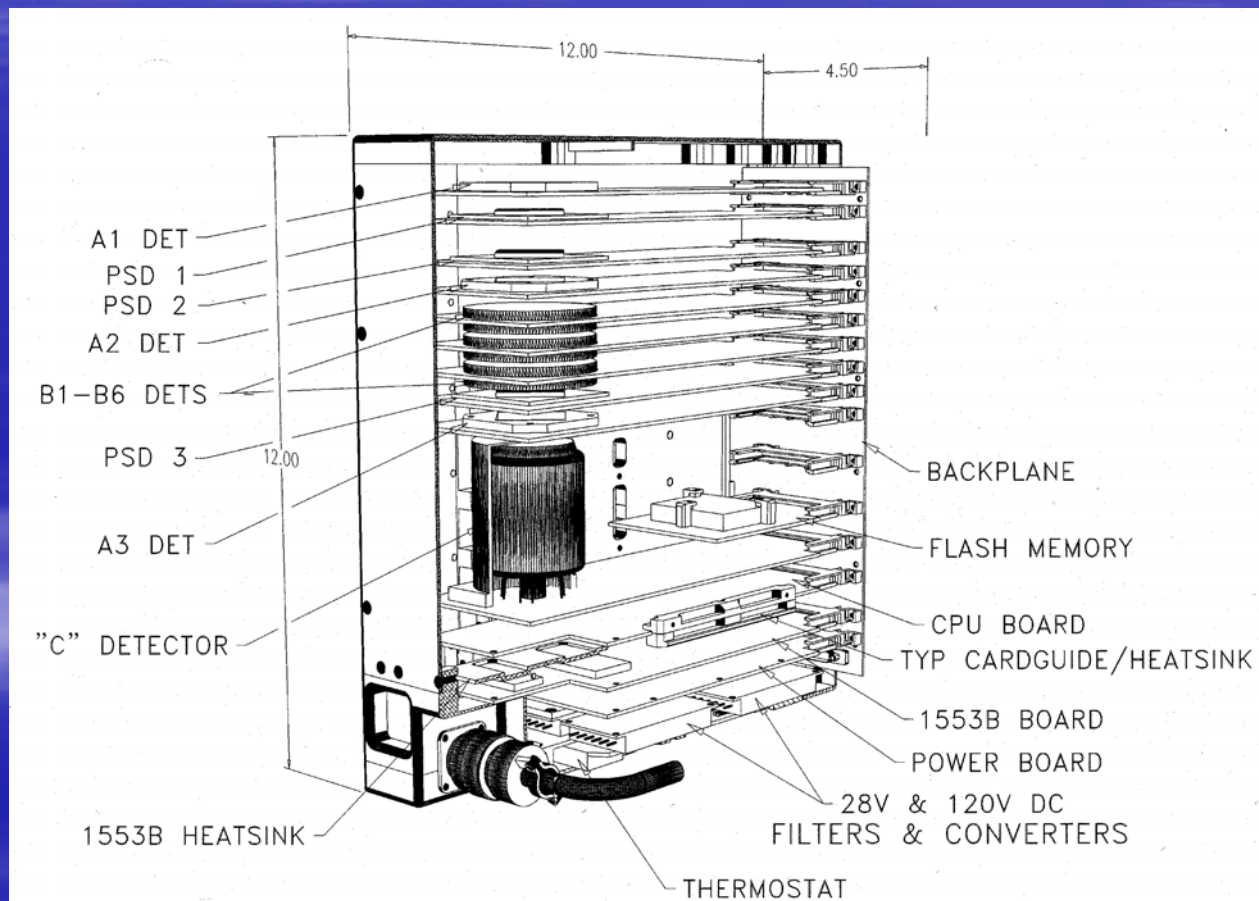
EV-CPDS

IV-CPDS

A1
PSD1
PSD2
A2
B1, B2
B3, B4
B5, B6
PSD3
A3
SPARE
SPARE
FLASH MEM
C DET
CPU
1553B
POWER

A1 DET
PSD 1
PSD 2
A2 DET
B1–B6 DETS
PSD 3
A3 DET
"C" DETECTOR
1553B HEATSINK

BACKPLANE
FLASH MEMORY
CPU BOARD
TYP CARDGUIDE/HEATSINK
1553B BOARD
POWER BOARD
28V & 120V DC
FILTERS & CONVERTERS
THERMOSTAT
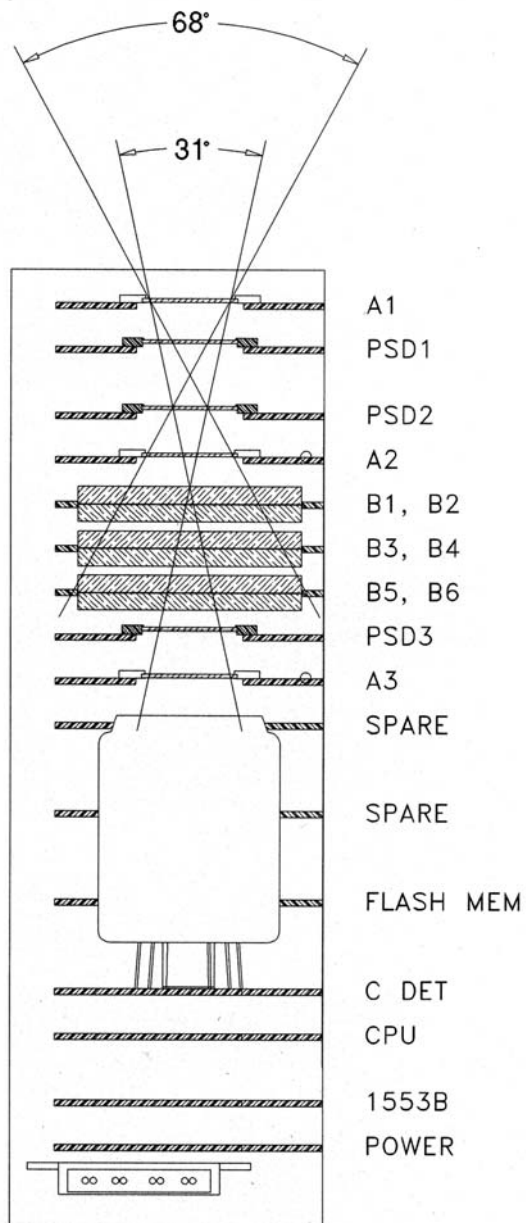
Detector Details

- **A Detectors**
  - Square Si detector, 30.0x30.0mm, 1.0mm thick
  - Top and bottom brass noise shield 5mil (0.127mm) thick

- **PSD Detectors**
  - Square Si strip detector, 24.0x24.0mm, 0.300mm thick
  - 24 strips on top surface and 24 strips on bottom surface, perpendicular to each other

- **B Detectors**
  - Cylindrical Lithium drifted Si detector, 58.4mm in diameter, 5mm thick.

- **C Detector**
  - Sapphire 50mm in diameter, and 10mm thick
 - Hamamatsu PMT

CPDS Collected Data

- Counter Data
  - Individual detector count rates for A1, A2, A3, B2, B4, B6 and C.
  - Number of events above detector threshold.
  - Written to file every minute.
- Event Data (Requires Trigger, A1 A2 coincidence)
  - ADC value (ΔE) from A, B, and C detectors.
  - ADC value (ΔE) and strip location for up to two events for each PSD detector plane.
  - Written to file every trigger.
- Engineering Data
  - Board and detector temperatures, power consumption, etc.
 - Written to file every 30 minutes.

CPDS Capabilities

- Minimum Proton A1 count energy of 20MeV.
- Minimum Proton coincident energy of 30MeV.
- Maximum stopping proton energy of ~95MeV
- Low energy H and He ion separation (stopping particles)
- Charged particle separation for minimum ionizing particles up to Z=11.
- Energy spectrum for charges with Z<4.
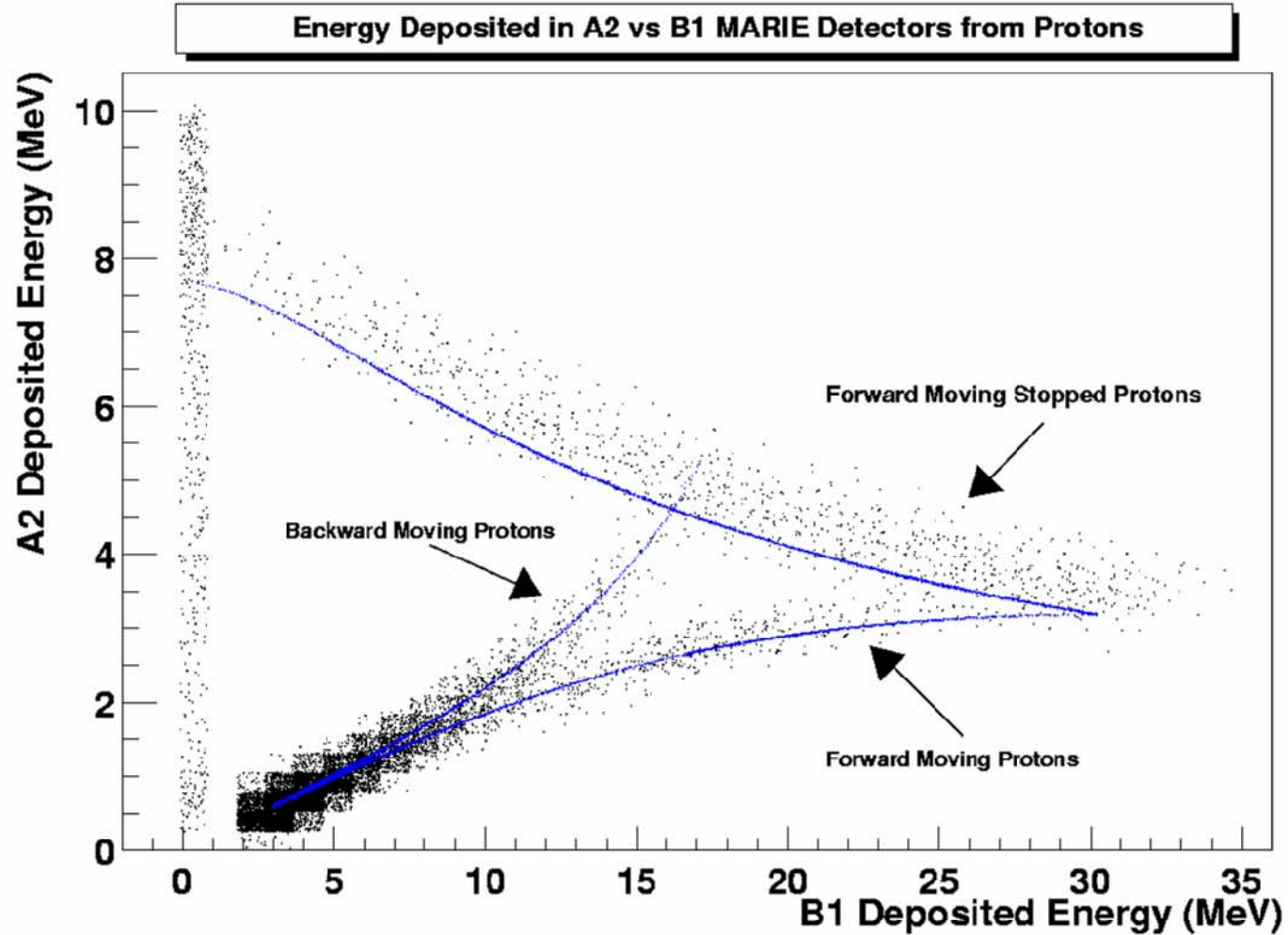- Proton spectrum up to ~120MeV and Helium up to ~300MeV/n.

Stopping Particles

Energy Deposited in A2 vs B1 MARIE Detectors

Protons
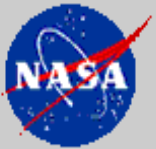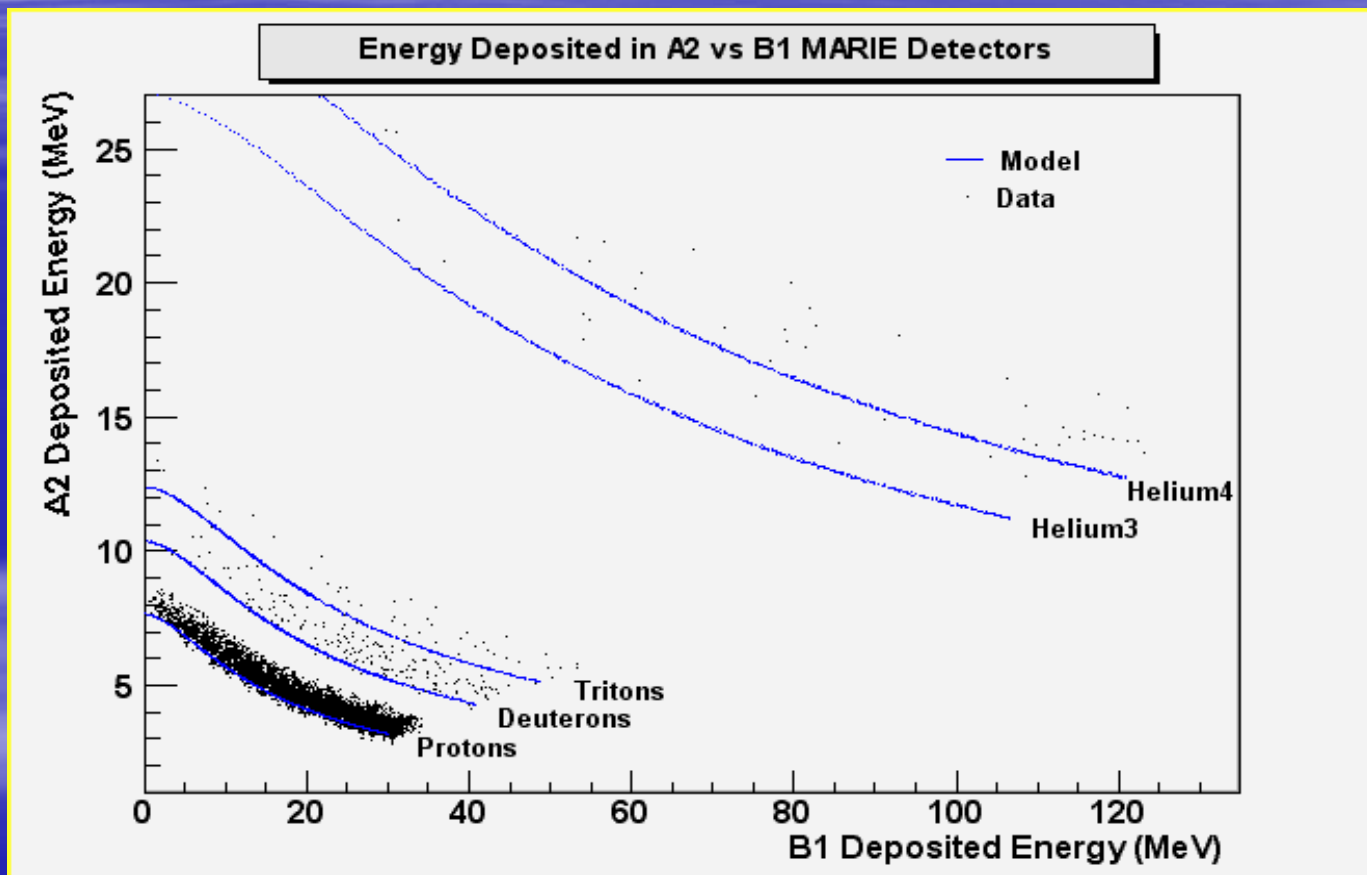
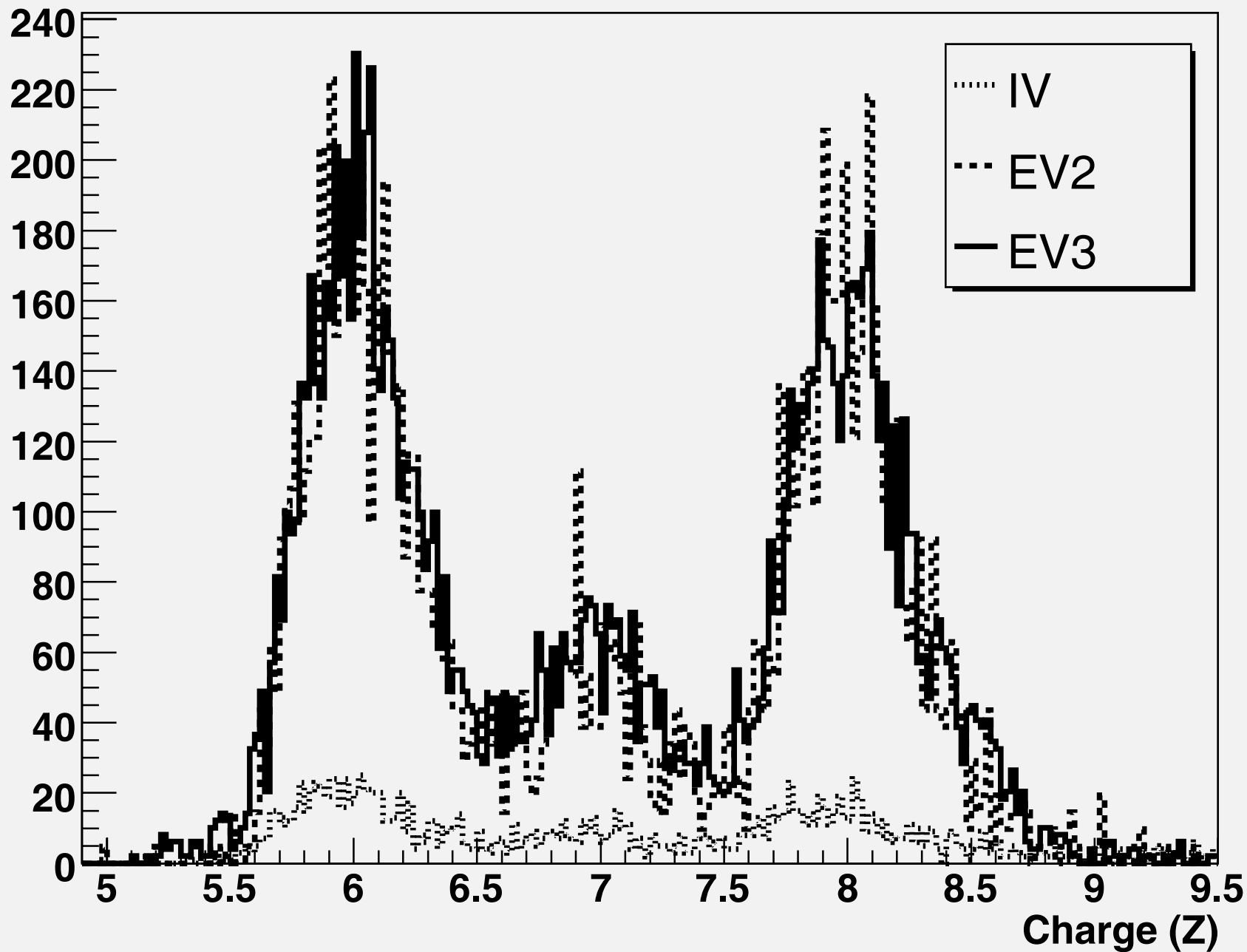Energy Deposited in A2 vs B1 MARIE Detectors from Protons

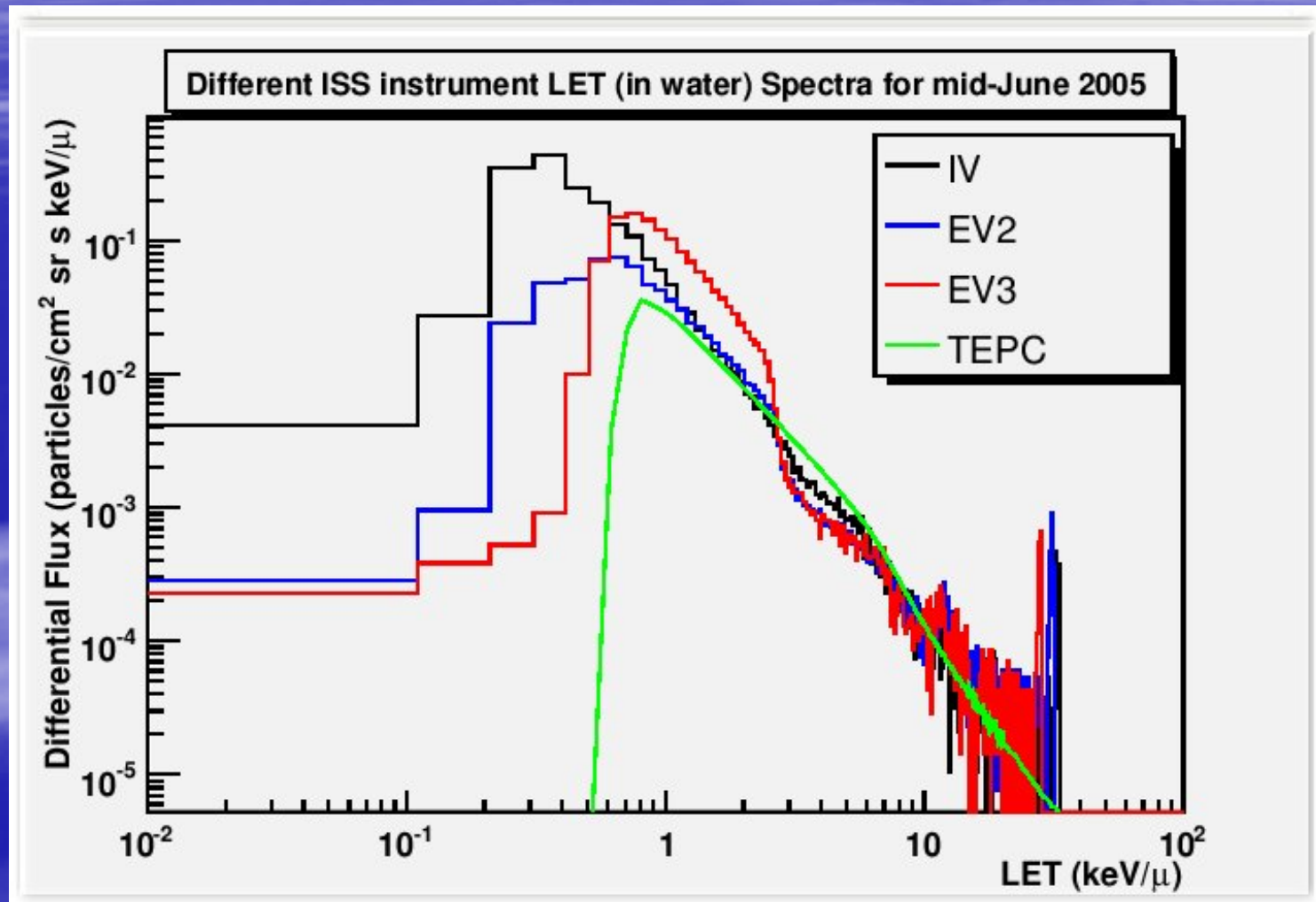Relative CNO Abundances Detected by ISS Instruments

Current Work

- A1 and A2 thresholds were changed last week. This will increase the number of high energy protons that are triggered on.
- Characterize the trigger threshold
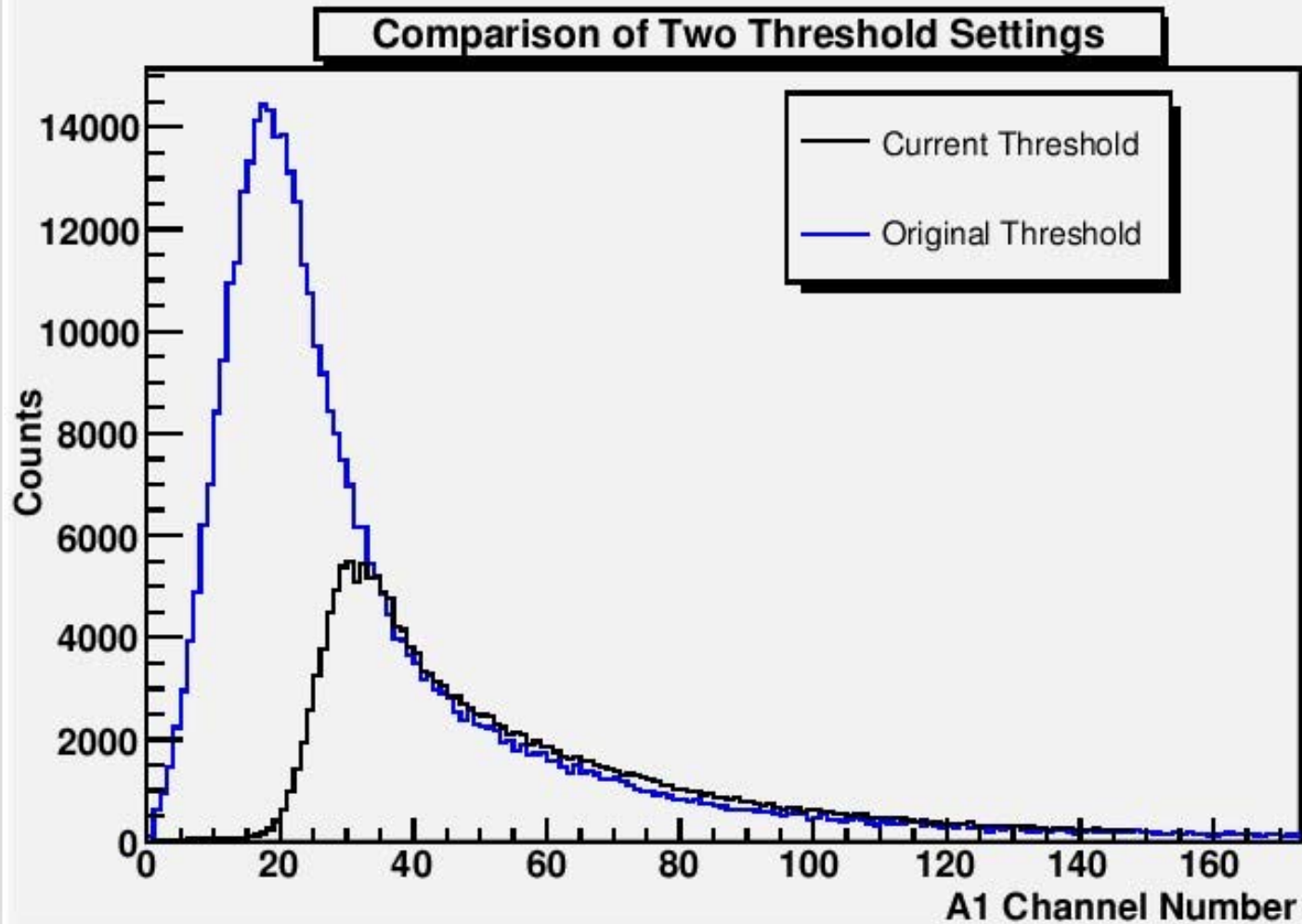- Data corrections (time stamp)
- ISS instrument comparison

ISS Instruments LET Spectra

Different ISS instrument LET (in water) Spectra for mid-June 2005

Threshold Change


Comparison of Two Threshold Settings

Summary

- The analysis of the CPDS instrument data (early 2002-present) has begun.
- The LEO proton spectrum from 30-120MeV will be measured
- The LEO He spectrum from 50-300MeV/n will be measured
- Minimum ionizing He-Ne relative abundances will be determined.
- The IV and EV offer the unique simultaneous observations inside and outside the ISS.
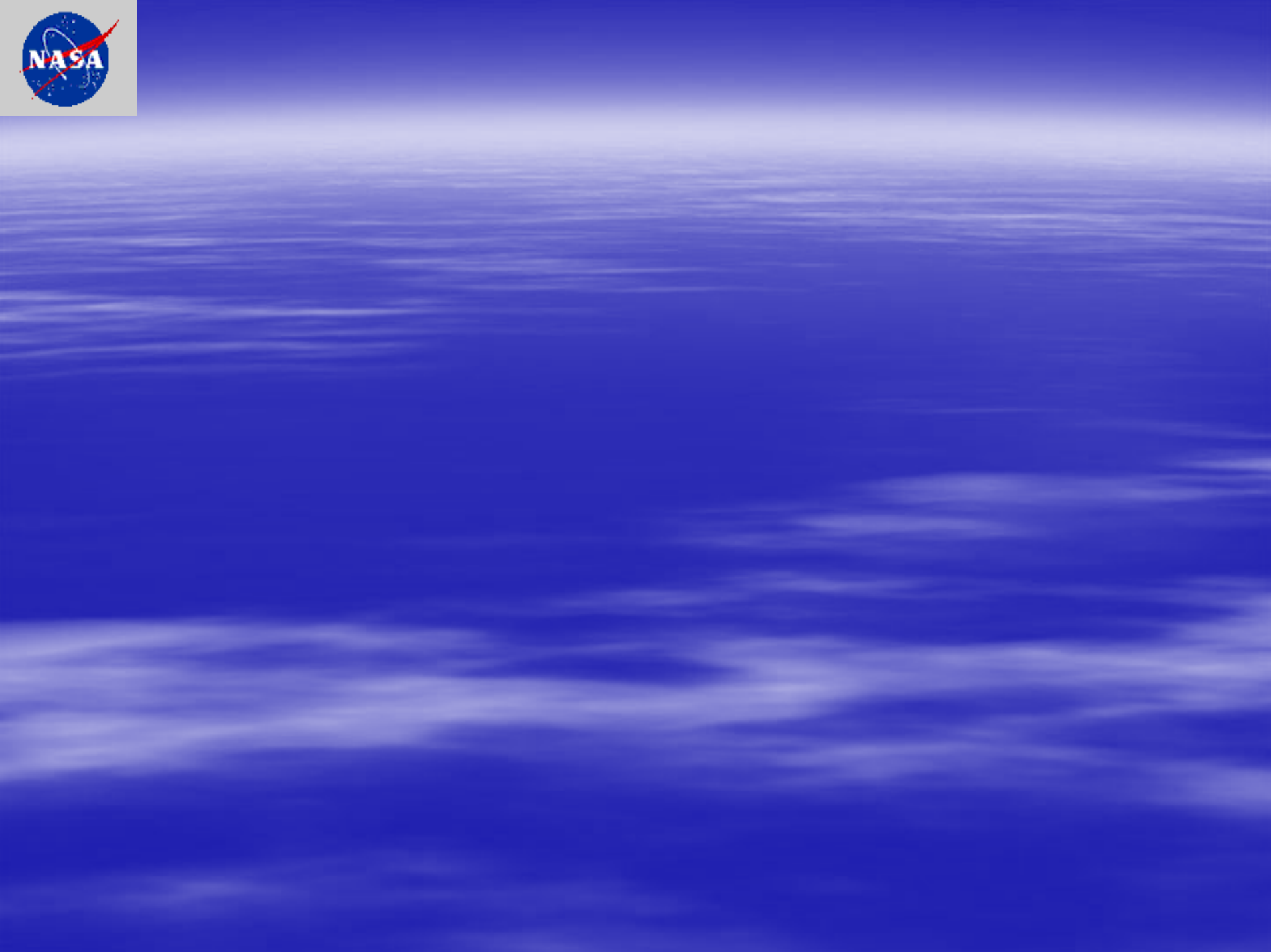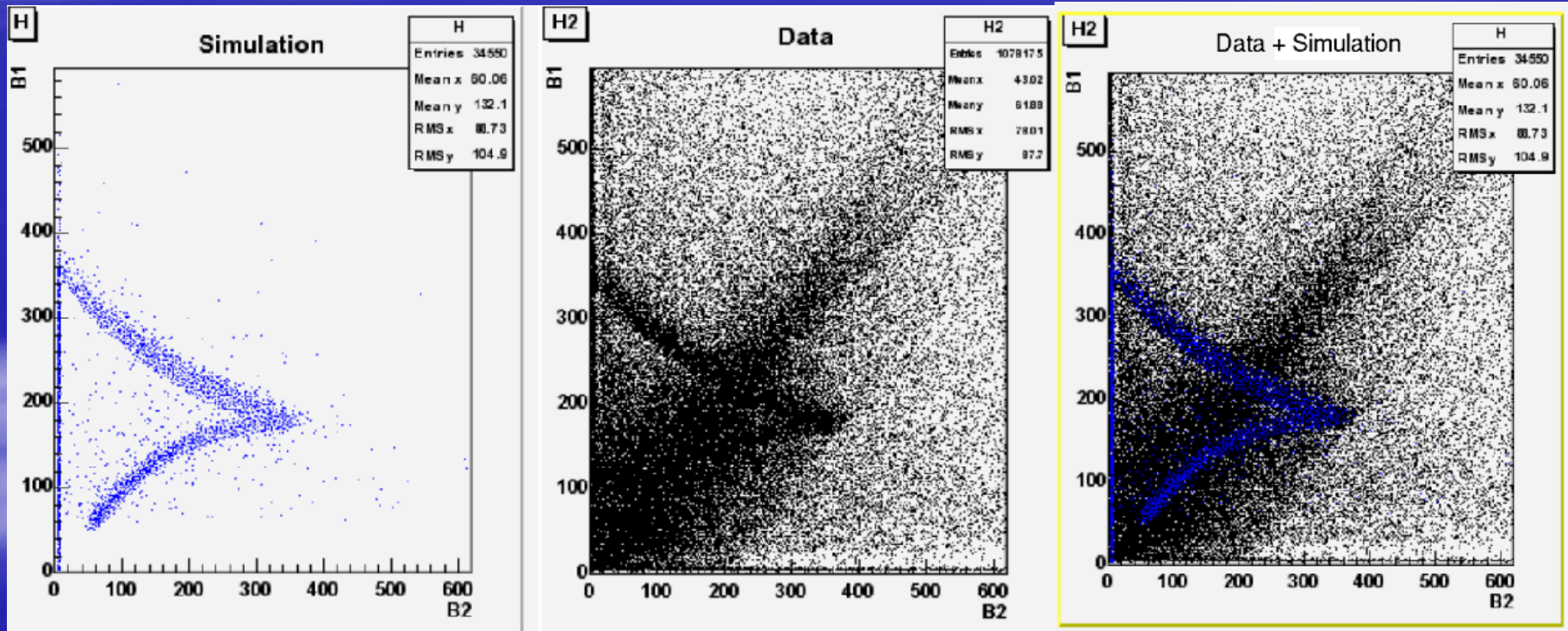
Calibration

- Detector calibration done using proton FLUKA simulation and in flight proton data.
- ADC offset determined by B detector pedestals and A detector offset is equal to zero.
- Scaling factors found by overlaying simulated and real data.

Example Calibration

Data Selection

- Cut on time between successive events (required due to CPU limitations in early data).
- Passes χ^2 fit, where $\chi^2 = \frac{1}{n} \sum_{i=0}^{n} (\Delta E_c^i(E, Z, A) - \Delta E_m^i)^2$, and n is the number of detectors that contain a signal.
- The calculated energy loss, ΔE_c^i , is from the Bethe-Bloch equation.
- Cut on $E \times \Delta E$ for stopping particles or fitted energy range for penetrating particles.
- Data selection cuts are optimized using a full Monte Carlo simulation.

CPDS Analysis Plan

```
Geometry ──────────┐
                   │
                   ▼
Source          FLUKA ──────► Reverse           CPDS
Spectrum                      Calibration ────► Algorithm
(Badhwar-O'Neill)──┘          (MeV->ADC)        Simulator
                   ▲                               │
                   │                               ▼
              Measured                          CPDS
              Particle                          Raw Data
              Spectra                           File
                   ▲                               │
                   │                               ▼
              Flux ◄──── Particle ◄──────────── CPDS
         ┌──► Calculation   Detection           Analysis
         │                  Efficiency
         │
Particle and ◄──── CPDS ◄──── CPDS ◄──── CPDS
Energy ID          Analysis   Raw Data    Instrument
                              File
```
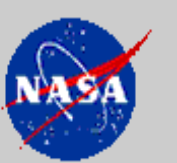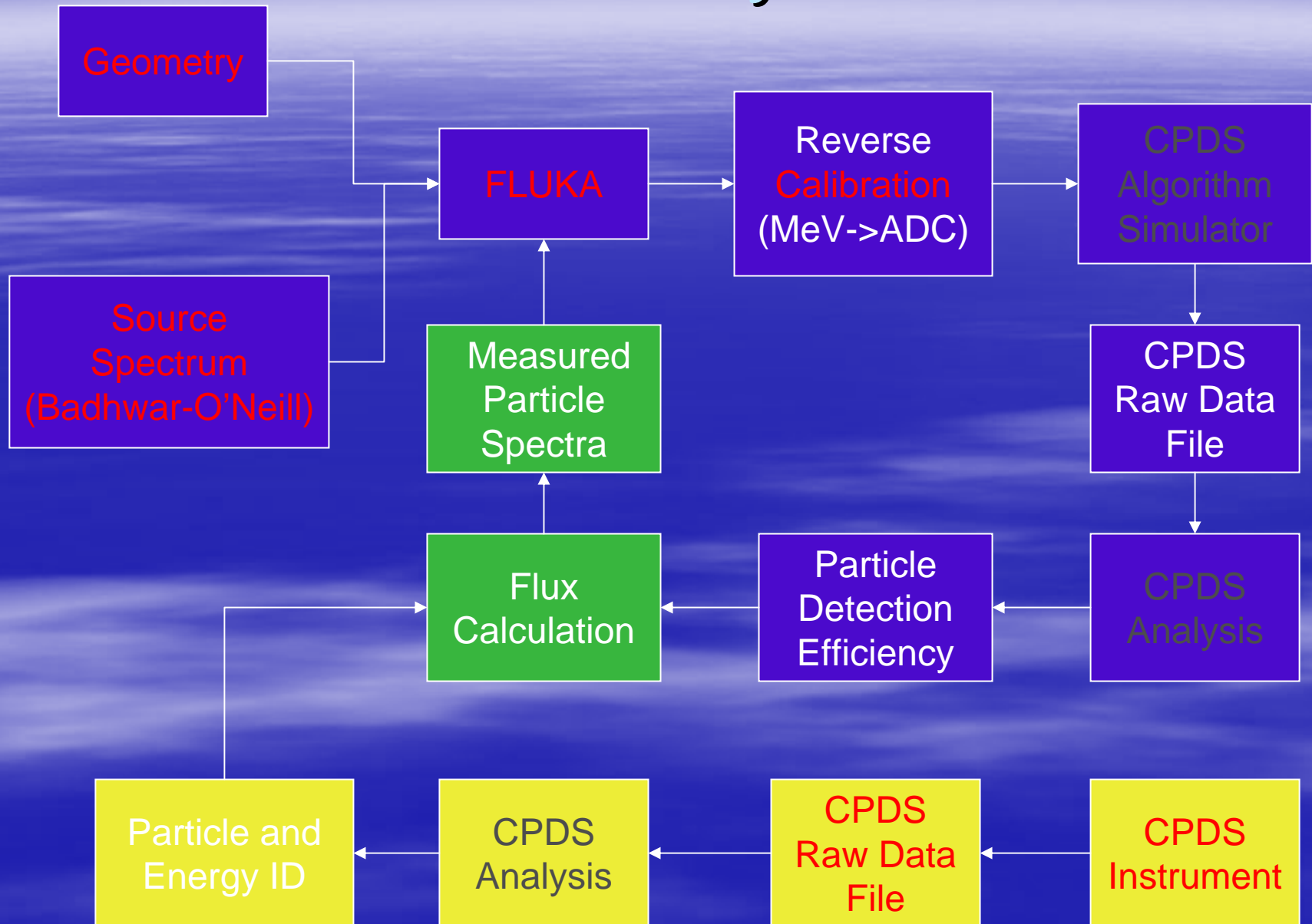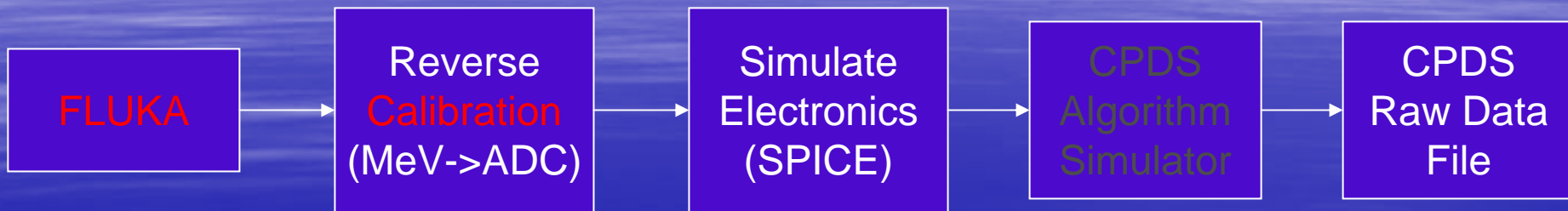
Possible Simulation Improvement

| FLUKA | → | Reverse Calibration (MeV->ADC) | → | Simulate Electronics (SPICE) | → | CPDS Algorithm Simulator | → | CPDS Raw Data File |

- Test such a simulation algorithm for existing instruments
- Useful for design and development of future instruments.

Monte Carlo Simulation

- FLUKA is used to simulate the expected energy losses in each detector.

- The algorithm simulation includes all processes that are done for data acquisition.

- Initial particle spectrum input is from updated Badhwar-O'Neill model (COSPAR 2004).

- Particles of all ions from H through Fe with energies of 10MeV to 10GeV, with relative abundances according to Simpson (1983).

Monte Carlo and Data Comparison
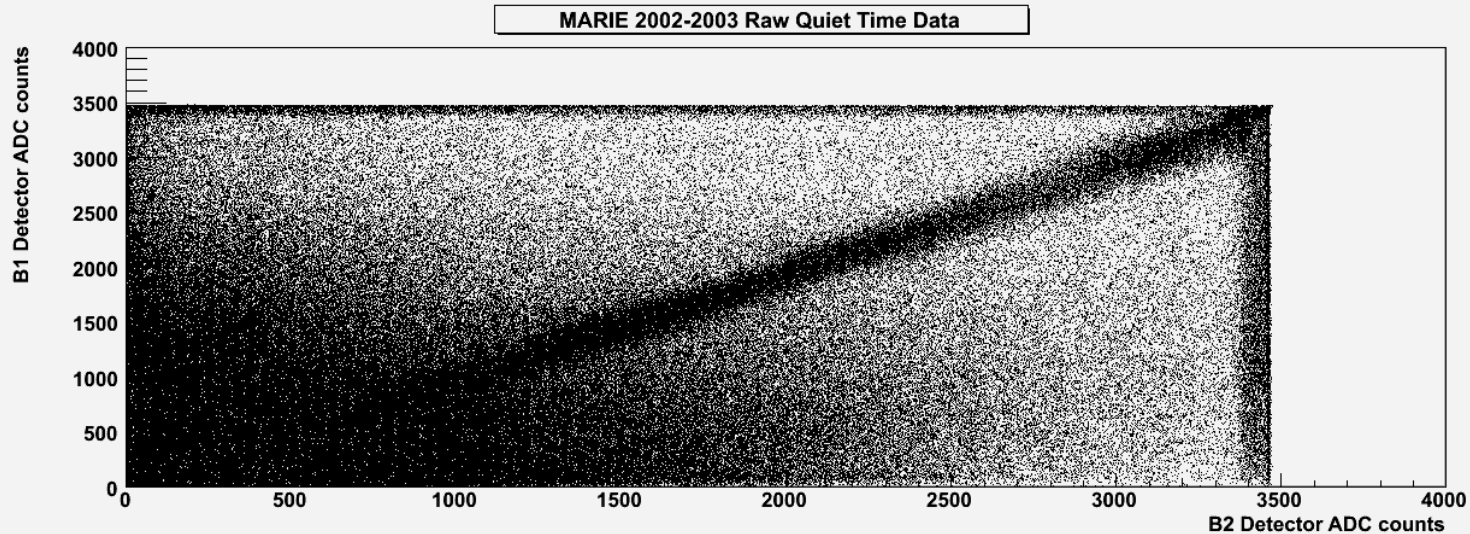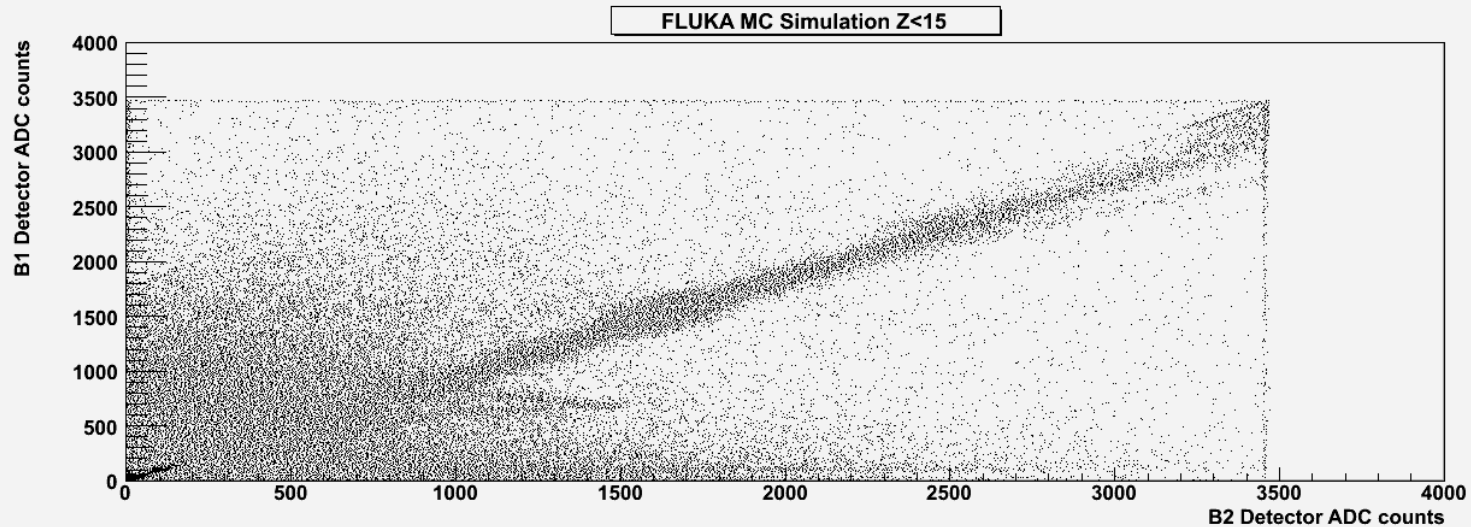
Flux Calculation

- Flux is calculated using

$$\phi = \frac{N(E)}{Gt\Delta E} \frac{1}{\varepsilon_s \varepsilon_d}$$

- G = Geometry factor (3.2 cm^2 sr for trigger)
- ε_d = dead time correction
- ε_s = Efficiency from MC
- t = total detection time
- Delta E = energy range
- N(E) = number of particles passing selection requirements